

CLAIMS

1. A method for performing a medical procedure by applying electromagnetic radiation (EMR) to a treatment area of a patient's body which may contain at least one chromophore, such radiation being of at least one wavelength absorbed by said chromophore, having a power profile with an average power (P_a) and peak power (P_p), (P_p) being insufficient to cause a change in the at least one chromophore which results in significant loss of absorption, and having a duration long enough for sufficient energy for the procedure to be applied at said power profile to the treatment area.
2. A method as claimed in claim 1, wherein said target area has a thermal relaxation time (TRT), and wherein said duration is greater than said TRT.
3. A method as claimed in claim 2, wherein said duration is substantially greater than the TRT.
4. A method as claimed in claim 1, wherein said peak power is less than 500 watts.
5. A method as claimed in claim 1, wherein said EMR is continuous wave, and wherein peak power and average power for said radiation over said duration are roughly the same.
6. A method as claimed in claim 1, where said chromophore is heated to a temperature which is no more than approximately 110°C so as to avoid vaporization of tissue.
7. A method as claimed in claim 1, wherein said procedure is hair removal, wherein said chromophore is melanin of a hair shaft in a hair follicle, and wherein said duration is sufficient for sufficient heat from said hair shaft to reach an outer root sheath of said follicle to damage stem cells located thereat.
8. A method as claimed in claim 1, wherein said procedure is hair removal, wherein said chromophore includes a heater in at least one follicle located in said target area, and

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wherein said power profile and duration are sufficient to at least damage at least one critical element of the follicle.

9. A method as claimed in claim 1, wherein said procedure is wrinkle removal,
5 wherein said chromophore is melanin at the dermis-epidermis (DE) junction, and
wherein said power profile and duration are sufficient to heat collagen in the patient
papillary dermis sufficiently to restructure such collagen.

10. A method as claimed in claim 1, wherein said procedure is destructions of
10 vascular lesions, wherein said chromophore is blood in the vascular lesion, and wherein
said duration is sufficiently longer, at said power profile, than the thermal diffusion time
of the vessel for bulk heating of the vessel.

11. A method as claimed in claim 1, wherein said wavelength is absorbed by melanin
15 in the patient's epidermis, including at the dermis-epidermis (DE) junction, and wherein
said power profile and duration are such that heat generated as a result of EMR
absorption in epidermal melanin can migrate to the skin surface and be removed
concurrent with irradiation, thereby controlling temperature increase in the epidermis
during irradiation.

12. A method as claimed in claim 1, including reapplying said EMR to said treatment
20 area with a power profile and duration selected to one of retarget the same chromophore
in the treatment area and target a different chromophore in the target area.

13. Apparatus for performing a medical procedure on a treatment area of a patient's
25 body containing at least one chromophore including a source of electromagnetic
radiation (EMR) of at least one wavelength absorbed by said chromophore, an applicator
applying the EMR to a treatment area of a patient's body, and controls causing the EMR
applied to the target area to have a power profile with an average power (P_a) and peak
30 power (P_p), (P_p) being insufficient to cause a change in the at least one chromophore
which results in significant loss of absorption, and to have a duration long enough for
sufficient energy for the treatment to be applied at said power profile to the treatment
area.

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14. Apparatus as claimed in claim 13, wherein said target area has a thermal relaxation time (TRT), and wherein said duration is greater than said TRT.

5 15. Apparatus as claimed in claim 14, wherein said duration is substantially greater than the TRT.

16. Apparatus as claimed in claim 13, wherein said peak power is less than 500 watts.

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17. Apparatus as claimed in claim 13, wherein said EMR is continuous wave, and wherein peak power and average power for said radiation over said duration are roughly the same.

15 18. Apparatus as claimed in claim 13, wherein said chromophore is heated to temperature which is no more than approximately 110°C so as to avoid vaporization of tissue.

19. Apparatus as claimed in claim 13, wherein said procedure is hair removal,
20 wherein said chromophore is a hair shaft in a hair follicle, and wherein said duration is sufficient for sufficient heat from said hair shaft to reach an outer root sheath of said follicle to damage stem cells located thereat.

20. Apparatus as claimed in claim 13, wherein said procedure is hair removal,
25 wherein said chromophore includes a heater in at least one follicle located in said target area, and wherein said power profile and duration are sufficient to at least damage at least one critical element of the follicle.

21. Apparatus as claimed in claim 13, wherein said procedure is wrinkle removal,
30 wherein said chromophore is melanin at the DE junction, and wherein said power profile and duration are sufficient to heat collagen in the papillary dermis sufficiently to restructure such collagen.

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22. Apparatus as claimed in claim 13, wherein said procedure is destructions of vascular lesions, wherein said chromophore is blood in the vascular lesion, and wherein said duration is sufficiently longer at said power profile than the thermal diffusion time of the lesion for bulk heating of the lesion.

5 23. Apparatus as claimed in claim 13, wherein said wavelength is absorbed by melanin in the patient's epidermis, including at the dermis-epidermis (DE) junction, and wherein said power profile and duration are such that heat generated as a result of EMR absorption in epidermal melanin can migrate to the skin surface and be removed
10 concurrent with irradiation, thereby controlling temperature increase in the epidermis during irradiation.

24. Apparatus as claimed in claim 23 including a mechanism which actively cools at least the portion of said skin surface over the treatment area at least substantially
15 concurrent with application of EMR to said treatment area.

25. Apparatus as claimed in claim 13 including a detector for at least one patient physiological condition, said controls being responsive to said detector for controlling at least one of EMR power profile and duration.

20 26. Apparatus as claimed in claim 13, wherein said radiation source is a low peak power laser source.

25 27. Apparatus as claimed in claim 13, wherein said radiation source is a low peak power non-coherent light source.

28. A method for performing a medical procedure on a target area of a patient's body, said target area having a thermal relaxation time (TRT) and including a highly absorbent heater portion, the method including applying electromagnetic radiation
30 (EMR) to at least the heater portion of said target area of at least one wavelength highly absorbed by said heater portion, of a duration close to or greater than said thermal relaxation time, and having a power profile sufficient over said duration to accomplish said medical procedure.

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29. A method as claimed in claim 28 wherein said duration is significantly greater than TRT.

5 30. A method as claimed in claim 28, wherein said target area has a thermal damage time (TDT) which is the time required at said power profile for said entire target area to reach a thermal destruction temperature; and wherein the duration of said radiation is substantially equal to said TDT.

10 31. A method as claimed in claim 30, wherein said duration (t) for the EMR is equal (TDT- δ), where δ is roughly the propagation time for heat from the heater portion to a non-heater portion of the target furthest from the heater.

15 32. A method as claimed in claim 30, wherein $TDT = TRT \cdot r(x, \Delta)$, where x is a geometrical factor and Δ is a temperature factor.

20 33. A method as claimed in claim 32, wherein $x = d_2/d_1$ where d_1 = size of heater portion and d_2 = size of total target, and wherein $\Delta = (T_2 - T_0)/(T_1 - T_0)$ where T_0 is target/heater temperature before irradiation, T_1 is the heater temperature and T_2 is the temperature at which irreversible thermal damage of the target area generally occurs.

25 34. A method as claimed in claim 30, wherein said target is a hair follicle, and said heater portion includes a pigmented hair shaft in said follicle, TDT being the time required for heat to the thermal destruction temperature to reach an outer sheath of the follicle.

30 35. A method as claimed in claim 30, wherein said target is a blood vessel, said heater portion including blood in the vessel, and TDT being the time required for heat to the thermal destruction temperature to reach through walls of the blood vessel in a target area.

36. A method as claimed in claim 30, wherein said target is collagen in the patient papillary dermis, said heater portion being melanin at the dermal-epidermal (DE)

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junction, and TDT being the time required for heat at the thermal destruction temperature to reach a desired depth in said papillary dermis.

37. A method as claimed in claim 30, wherein said power profile is such that at TDT, the entire target area is at a temperature of at least the thermal destruction temperature, but substantially no tissue outside the target area is at or above the thermal destruction temperature.

38. A method as claimed in claim 28, including cooling the patient's skin in an area over said target area to remove heat from the patient's epidermis.

39. Apparatus for performing a medical procedure on a target area of a patient's body, said target area having a thermal relaxation time (TRT) and including a highly absorbent heater portion, including: a source of electromagnetic radiation (EMR) of at least one wavelength highly absorbed by said heater portion; an applicator for applying EMR from said source to at least the heater portion of said target area; and controls for operating at least one of said source and said applicator to apply EMR to said target area for a duration significantly greater than said thermal relaxation time and with a power profile sufficient over said duration to accomplish said medical procedure.

40. Apparatus as claimed in claim 39, wherein said target has a thermal damage time (TDT) which is the time required at said power profile for said entire target to reach a thermal destruction temperature; and wherein the duration of said radiation applied to said target area is substantially equal to said TDT.

41. Apparatus as claimed in claim 40, wherein said duration (t) during which EMR is applied to the target is equal (TDT- δ), where δ is roughly the propagation time for heat from the heater portion to a non-heater portion of the target furthest from the heater portion.

42. Apparatus as claimed in claim 40, wherein $TDT = TRT \cdot r(x, \Delta)$, where x is a geometrical factor and Δ is a temperature factor.

43. Apparatus as claimed in claim 42, wherein $x = d_2/d_1$ where d_1 = size of heater portion and d_2 = size of total target, and wherein $\Delta = (T_2 - T_0)/(T_1 - T_0)$ where T_0 is target/heater temperature before irradiation, T_1 is the heater temperature and T_2 is the temperature at which irreversible thermal damage of the target area generally occurs.

5 44. Apparatus as claimed in claim 39, including a mechanism operative at least during application of EMR to said target area which cools the patient's skin in an area over said target area.

10 45. A method for performing a medical procedure on a target area of a patient's body, said target area including a highly absorbent heater portion, the method including applying electromagnetic radiation EMR to at least the heater portion of said target area of at least one wavelength highly absorbed by said heater portion, having a power profile which heats said heater portion to a temperature T which is greater than a thermal
15 damage temperature for at least a portion of the target area to be damaged, but less than a collapse temperature at which said heater portion undergoes a change which results in significant loss of absorption at said at least one wavelength, and having a duration sufficient with said power profile to accomplish said medical procedure.

20 46. A method as claimed in claim 45, wherein said target has a thermal damage time (TDT) which is the time required for said entire target to reach said thermal destruction temperature at said power profile, and wherein said duration is substantially equal to TDT.

25 47. A method as claimed in claim 45, wherein at said collapse temperature, said heater portion undergoes a phase transition causing at least one of bleaching, melting, boiling, bubble formation and other destructive process.

30 48. A method as claimed in claim 45, wherein said heater portion is a naturally occurring chromophore in the patient's body.

49. A method as claimed in claim 45, wherein said heater portion is at least in part an artificial chromophore introduced to said target area.

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50. A method as claimed in claim 45, wherein said medical procedure is hair removal, wherein said heater portion includes a hair shaft in a hair follicle which hair shaft has a collapse temperature of up to 250°C, and wherein said duration is 0.5 ms to 20 sec.

51. A method as claimed in claim 45, wherein said medical procedure is removal of vascular lesions, and wherein said duration is 0.5 ms to 20 sec.

52. A method as claimed in claim 45, wherein said medical procedure is collagen remodeling and wherein said duration is 100 ms to 20 sec.

53. A method as claimed in claim 45 including repeating said applying step at least one additional time to further damage at least selected portions of said target area.

54. A method as claimed in claim 53 wherein heaters in a target area are not uniform and therefore have different collapse temperatures, wherein, during a selected performance of said applying step, portions of said target area heated by a heater are treated without exceeding the thermal collapse temperature of the heater, and wherein, during subsequent performance of the applying step, the thermal collapse temperature for said heaters is exceeded without exceeding the thermal collapse temperature of heaters heating portions of the target area for which treatment is not completed.

55. A method as claimed in claim 45 wherein said power profile is such that the temperature of said heater is substantially constant for said duration.

56. A method as claimed in claim 45 wherein said power profile and duration are such as to result in hyperthermia in said target area to accomplish said medical procedure.

57. Apparatus for performing a medical procedure on a target area of a patient's body, said target area including a highly absorbent heater portion, including: a source of electromagnetic radiation (EMR) of at least one wavelength highly absorbed by said

heater portion, an applicator applying said radiation to at least the heater portion of said target area, and controls for at least one of said source and said applicator to cause said EMR applied to the target area to have an power profile which heats said heater to a temperature T which is greater than a thermal damage temperature for at least a portion of the target to be damaged, but less than a collapse temperature at which said heater
5 portion undergoes a change which results in significant loss of absorption at said at least one wavelength, and of a duration sufficient with said power profile to accomplish said dermatology procedure.

10 58. Apparatus as claimed in claim 57, wherein said target has a thermal damage time (TDT) which is required for said entire target to reach said thermal destruction temperature at said power profile, and wherein said duration is substantially equal to TDT.

15 59. Apparatus as claimed in claim 57, wherein said EMR source is an optical radiation source.

60. Apparatus as claimed in claim 57, wherein said power profile is such the temperature of said heater is substantially constant for said duration.

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61. A method for performing a medical procedure on a target area of a patient's body, said target area including at least one absorbent heater portion and at least one non-heater portion having weak absorption to no absorption, said at least one non-heater portion being spaced to varying degrees from said at least one heater portion, the method
25 including applying electromagnetic radiation (EMR) to at least heater portions of said target area of at least one wavelength highly absorbed by said heater portions, having a power profile which heats said heater portions to a temperature T which is greater than a thermal damage temperature for the portions of the target area to be damaged, but less than the collapse temperature at which said heater portions undergo a change which
30 results in significant loss of absorption at said at least one wavelength, and of a duration sufficient with said energy profile to permit the heating of substantially all of said target area from said heater portions to a temperature sufficient to accomplish said medical procedure.

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62. A method as claimed in claim 61, wherein the temperature to which substantially all of said target area is heated is at least equal to a thermal destruction temperature for said target area.

5 63. A method as claimed in claim 61, wherein there are a plurality of target areas in an aperture being irradiated by said EMR, each of said areas being of a size d_2 , and centers of said target areas being spaced by a distance d_3 , and wherein the ratio of fluence F_{NS} at which damage outside a target area occurs to fluence F_S at which selective damage of a complete target area occurs is $F_{NS}/F_S = (d_3/d_2)^n$, wherein n is dependent on
10 target shape.

64. A method for performing a medical procedure by applying electromagnetic radiation (EMR) of appropriate wavelength to a treatment area of a patient's body, such wavelength being absorbed by melanin in the patient's epidermis, including at the
15 dermis-epidermis (DE) junction, and wherein said EMR has a power profile and duration which are sufficient to effect the medical procedure and are such that heat generated as a result of EMR absorption in epidermal melanin can migrate to the skin surface and be removed concurrent with irradiation, thereby controlling temperature increase in the epidermis during irradiation.

20 65. A method as claimed in claim 64, including actively cooling said skin surface at least during said duration.

66. Apparatus for performing a medical procedure on a patient's body including: a
25 source of electromagnetic radiation (EMR) of a wavelength appropriate for said procedure, said wavelength being absorbed by melanin in the patient's epidermis, including at the dermis-epidermis (DE) junction, an applicator for applying the EMR to a treatment area of the patient's body, and controls for at least one of said source and said applicator which cause said EMR to be applied with a power profile and a duration to
30 effect said medical procedure and which are such that heat generated as a result of EMR absorption in epidermal melanin can migrate to the skin surface and be removed concurrent with irradiation, thereby controlling temperature increase in the epidermis during irradiation.

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67. Apparatus as claimed in claim 66, wherein said source is a source of optical radiation.

68. Apparatus as claimed in claim 66, including a mechanism for actively cooling said skin surface at least during said EMR duration, facilitating the removal of heat therefrom.

69. A method for performing a medical procedure on a target area of a patient's body, said target area including a highly absorbent heater portion, the method including applying electromagnetic radiation (EMR) to at least the heater portion of said target area of at least one wavelength highly absorbed by said heater portion, having a power profile which heats said heater portion to a temperature T, said applying step having a duration sufficient with said power profile to accomplish said medical procedure, and said power profile resulting in the temperature T of said heater being substantially constant during said durations.

70. A method as claimed in claim 69, wherein said power profile results in optical power decreasing substantially exponentially during said duration.

71. Apparatus for performing a medical procedure on a target area of a patient's body, said target area including a highly absorbent heater portion, including:

a source of electromagnetic radiation (EMR) of at least one wavelength highly absorbed by said heater portion, an applicator applying said radiation to at least the heater portion of said target area, and controls for at least one of said source and said applicator to cause said EMR applied to the target area to have a power profile which heats said heater to a temperature T, said EMR having a duration sufficient with said power profile to accomplish said medical procedure, and said power profile resulting in the temperature T of said heater being substantially constant during said durations.

72. An apparatus as claimed in claim 71, wherein said power profile results in optical power decreasing substantially exponentially during said duration.